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AUTHOR Lewis, Mary Jo; Jacobs, Richard S.
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ABSTRACT

A planned maintenance system, which was implemented at Washington State University (WSU), uniquely integrates functions of equipment inventory, scheduling, time reporting, project management, materials inventory, and billing. Management now has immediate access to equipment data, maintenance status, and costs. Staff requirements are readily defined through standardized task assignments. In addition, schedules, budget requirements, and resources adjustments are determined with the aid of detailed, up-to-date reports. Prior to implementation of the planned maintenance system: WSU was unable to identify, schedule or plan effectively; inefficient use of maintenance staff prevailed; and maintenance reports lacked sufficient detail and were time consuming to prepare. The first task in design of the system was to identify and classify the type of equipment for inventory. These classifications were assigned a number that corresponds to the item numbers in the stores inventory system. Next, the types of maintenance for each classification were analyzed. An analysis was also made of the time required to maintain equipment in 19 buildings to determine the number of employees needed. A list of the equipment inventory classifications is included, along with a diagram showing systems relationships. (SW)

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Progressive Planned Maintenance

Mary Jo Lewis
Richard S. Jacobs

University Computing Services
Washington State University
Pullman, Washington 99163-1230

Abstract

The Physical Plant Department at Washington State University had classic equipment maintenance problems. Management was unable to identify, schedule, or plan maintenance effectively; inefficient use of maintenance staff prevailed. Maintenance reports lacked sufficient detail, and were cumbersome and time consuming to prepare. The Planned Maintenance System implemented at WSU uniquely integrates functions of equipment inventory, scheduling, time reporting, project management, materials inventory, and billing. Management now has immediate access to equipment data, maintenance status and costs. Staff requirements are readily defined through standardized task assignments. Schedules, budget requirements, and resource adjustments are determined with the aid of detailed, up-to-date reports.

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INTRODUCTION

The Physical Plant Department at Washington State University, Pullman, maintains facilities, grounds and equipment for a large institution situated in a rural community. A long term goal to improve the efficiency and effectiveness of the large Physical Plant operation was realized when the Physical Plant Department and University Computing Services designed and developed a system for planned maintenance of equipment using the integrated university database. Equipment for the purposes of this application is defined as fixed assets attached to the building at construction. University Computing Services, the administrative data processing unit at Washington State University, maintains a university-wide database system on an AMDAHL 470/V8. The database utilizes the ADABAS database management system. Programming for the Planned Maintenance System for equipment is in the NATURAL and COBOL programming languages.

BACKGROUND

Prior to 1980, Washington State University lacked a completed inventory of equipment. Regular, scheduled maintenance was impossible because neither the identity nor location of the equipment was available. Maintenance of equipment was done primarily when a breakdown occurred or a potential problem was otherwise discovered. The maintenance staff was alternately very busy or faced with idle time. When maintenance was performed there was no way to assure the same work was done on each piece of equipment for the same problem or service. Lack of parts caused frequent service delays because there was no ability to coordinate parts requirements. Although repair and emergency service costs were high, the Physical Plant management lacked the information to analyze the source of the costs. Maintenance budget requests to correct the situation were difficult to justify. However, the university administration recognized the long term necessity of adequate equipment maintenance and a Planned Maintenance System development project was approved.

SYSTEM DESIGN

The Planned Maintenance System for equipment was designed to integrate the functions of scheduling, time reporting, project management, stores inventory, and billing. A diagram of system relationships is shown on Figure 1. The systems for stores inventory and billing were already in place at Washington State University but the systems for time reporting and project management had to be developed in parallel with the system for equipment maintenance.

Equipment Maintenance, Scheduling, and Instructions

The first task was to identify and classify the type of equipment for inventory. These classifications were assigned a number which corresponds to the item numbers in the stores inventory system. A list of the equipment inventory classifications is shown on Figure 2. In February, 1980, a

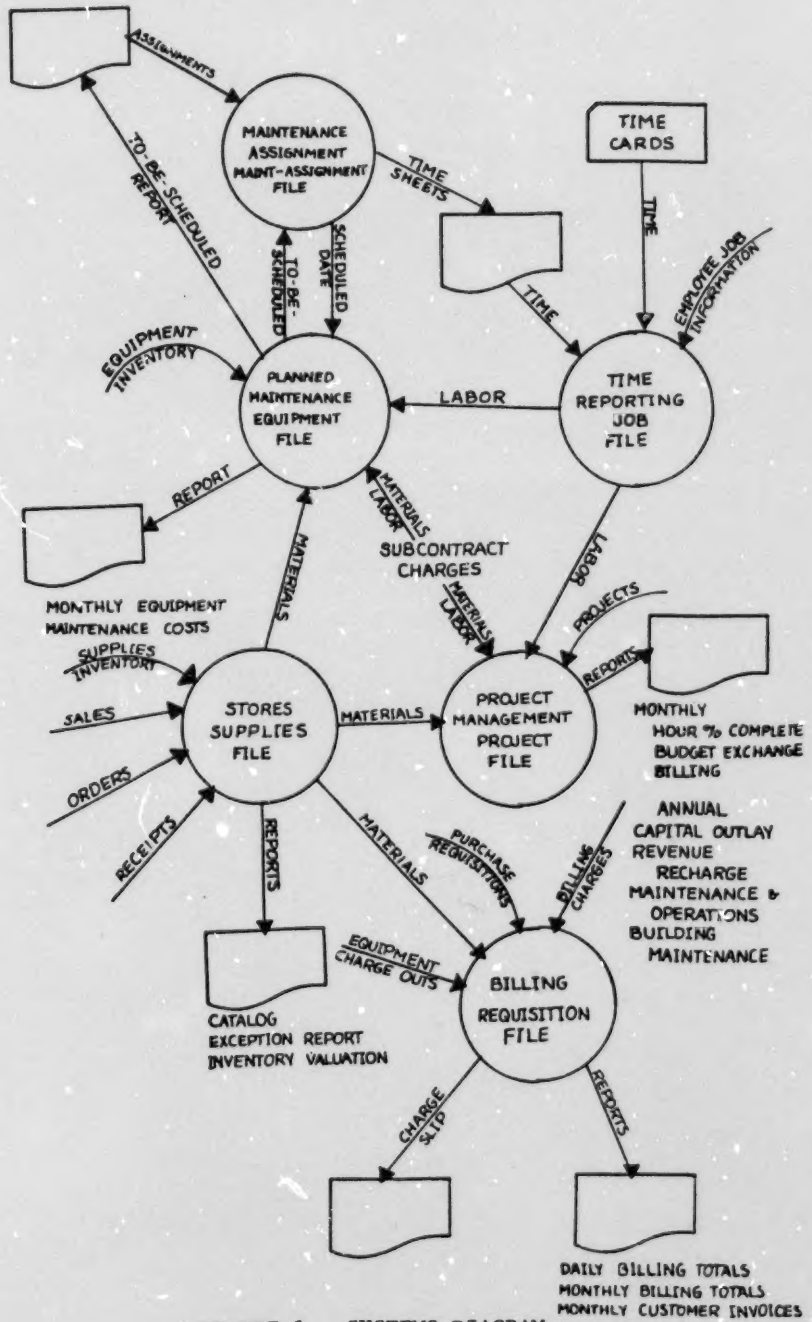

FIGURE 1. SYSTEMS DIAGRAM

EQUIPMENT INVENTORY CLASSIFICATIONS

MAINTAINABLE EQUIPMENT

Aftercooler
Air Compressor
Air Damper
Air Filter
Aisle/Stair Light
Backflow Preventer
Chiller
Clock
Condensate Meter
Condensate Pump
Control Valve
Converter
Cooling Coil
Cooling Tower
Damper Operator
Deionized Tank Set
Distribution Panelboard
Door Closer
Door Lockset
Drying Cabinet
Electric Steam Generator
Electric Water Cooler
Emergency Eye Wash
Emergency Generator
Evaporative Cooler
Exhaust Fan
Exit Device
Exit/Directional Signs
Expansion Tank
Extinguisher System CO_2
Faucet
Fire Alarm System
Fire Curtain
Fire Extinguisher
Fire Sprinkler System
Fire Standpipe
Fixed Furniture
Fume Hood
Furnace
Gate/Globe Valve
Halon Fire System
Heating Coil
Hose Rack
Hot Water Heater
HVAC Mech. Room Unit
Hydrant (Fire)
Lab Sink
Lab Table Outlet
Lavatory Fixture
Light Fixture
Low Pressure Boiler
Main Distribution Panel
Motor Control Center
Pipe Strainer
Power Transformer
Primary Switchgear
Pump
Purge System
Quality Control Light
Receiver-Controller
Refrigeration Compressor
Resisivity Monitor
Safety Shower
Sash Hardware
Smoke Hatch
Steam Reducing Valve
Sump Pump
Supply Fan
Thermal Recovery Unit
Thermostat
Urinal
Water Closet
Water Softener
Vacuum Pump

COMPONENTS

Air Filter Gauge
Ballast
Belt
Bearing
Chemical Feed Pump
Chemical Monitor
Component Fan
Component Pump
Compressor
Condensor
Control Valve
Electro-Pneumatic Controller
Engine
Evaporation Valve
Evaporator
Fan Sheave
Filter (Air)
Flame Fail Device
Float Switch
Flow Control Valve
Flush Valve
Generator
High Pressure Switch
Low Pressure Switch
Mixing Box
Motor
Motor Sheave
Oil Safety Switch
Pressure Reducing Valve
Recirculating Pump
Relief Safety Valve
Static Pressure Regulator
Steam Trap
Transfer Switch
Unfired Pressure Vessel
Volume/Control Terminal Unit
Water Regulating Valve

FIGURE 2. MAINTENANCE CLASSIFICATIONS

crew of seven people started taking a physical inventory of equipment in 120 buildings. It took almost a year to inventory approximately 75,000 items. Of these, only 30,000 items were determined to be maintainable items. Components of maintainable equipment were included for identification, performance tracking and parts requirements. Some items have been grouped for maintenance but retain individual identity for location and parts tracking. Each maintainable equipment record contains a project number, recommended maintenance services, history of maintenance labor hours and costs, and history of maintenance materials costs. A full description of the equipment is provided for parts requirements, and a specific location is designated.

After the inventory classifications were established and while the inventory was taken, the types of maintenance for each classification were analyzed. Manufacturer warranty requirements and maintenance recommendations were used to develop a set of standardized maintenance instructions for each equipment classification. Each maintenance instruction set specifies a frequency, shown on Figure 6, a task time, a recommended craft and a maintenance supervisory area. Maintenance supervisory areas and crafts are shown on Figure 3. The maintenance instruction set number is the key to the specific maintenance service on the equipment record. Each equipment classification may have up to ten different maintenance services. A total of 310 different maintenance instructions are required to maintain 156 different types of equipment representing 30,000 inventory items. The online system for equipment, developed in the summer of 1981, automatically attaches all appropriate maintenance services to the maintainable equipment record when it enters the system. The maintenance due dates are assigned separately.

MAINTENANCE SUPERVISORY AREAS	MAINTENANCE CRAFTS
Carpenter Shop	Carpenter
Controls Shop	Control Technician
Electrical Shop	Electrician
Electronics Shop	Electronic Technician
Janitor Shop	Janitor
Life Safety Shop	Life Safety Technician
Machine Shop	Machine Mechanic
Maintenance Mechanics Shop	Maintenance Mechanic Fan Balancer
Plumbing Shop	Plumber
Refrigeration Shop	Refrigeration Mechanic
Water Treatment Shop	Water Treatment Specialist

FIGURE 3. SUPERVISORY AREAS AND CRAFTS

Time Reporting

The maintenance staff was accustomed to reporting time daily by hours and fractions of hours. The time was reported against a project or work order as regular time or overtime. In order to post hours and cost to the equipment record, the Planned Maintenance System required an equipment inventory number and type of maintenance to also be reported. An online system for time reporting was developed and pay rates were placed in the employee database keyed by social security number. Hours, reported by employee, are converted to cost using the individual's pay rate, in order to post equipment and project records.

Project Management

The Physical Plant Department used a manual bookkeeping system to account for work units and cost centers. An online system for project management was developed in the Spring of 1981. In addition to maintenance projects, the system tracks costs for construction work orders and overhead accounts. Costs for facility maintenance as well as equipment maintenance are posted to maintenance projects. The system was designed to post projects with labor hours and costs from the time reporting system, materials costs from the stores inventory system, and subcontract charges from the billing or stores inventory systems.

Stores Inventory and Billing

A physical inventory of supplies and parts in the Physical Plant storeroom was taken in the Spring of 1981. Approximately 12,000 items in the storeroom were inventoried and coordinated in the database with items already in the stores inventory system. Modifications were made to existing inventory and billing programs to accommodate equipment maintenance, equipment charges, labor costs, and project management. Three online COBOL subroutines were developed to post equipment records and projects. These subroutines are accessed from the existing inventory and billing systems and from the new time reporting system.

IMPLEMENTATION

The maintenance instructions were placed in the university database in March, 1981. The equipment inventory was placed in the database in May, 1981, with the appropriate maintenance instruction set keys for each piece of inventory. In the summer of 1981 the modified stores inventory and billing systems, and the new time reporting and project management systems were implemented.

An analysis was made of the time required to maintain equipment in 19 buildings to determine the number of employees to commit to planned

maintenance. Physical Plant management decided to implement planned maintenance in the 19 buildings and dedicated a staff of 18 to this task.

These buildings had 12,000 pieces of maintainable equipment and although the Physical Plant Department had the ability to assign maintenance dates to specific services it would have taken an inordinate amount of time to assign the dates manually. Critical to the success of the system was finding a means to assign the first maintenance dates automatically.

An algorithm was developed by which a first maintenance date was assigned to each maintainable equipment record. A date was assigned to the maintenance service of the least frequency, e.g. five years, and the other services were projected on the basis of the first date. Maintenance task times for all services were projected for the five year period. A five year, 260 week table of the number of assignable (available) staff hours committed to planned maintenance was built, taking holidays into consideration. Other elements in the table were hours already assigned, and a date for the week. Dates were assigned to maintenance services when the task time plus hours assigned did not exceed assignable hours. Other services were projected by adding task time of the service to assigned hours. The objective was to avoid overassignment of work which could have resulted in distorted deferred maintenance figures from the outset and an unmanageable workload. The first maintenance dates were assigned in February, 1982, and the first planned maintenance was performed in March, 1982.

HOW IT WORKS

Each maintenance area supervisor receives a weekly report of equipment maintenance due by building. A sample of this report is shown on Figure 4. This report reflects what is due two weeks in advance, although the date period is flexible. Maintenance services which have already been scheduled but not yet completed, also appear on this report, along with the scheduled date. The supervisor assigns the work to specific employees, taking into consideration the task times. The assignments are entered at the terminal and can be revised until the time sheet is printed. When the time sheet is printed, a scheduled date for the maintenance service is recorded on the equipment record. The specific maintenance instructions to do the work assigned are printed, along with the time sheets. A sample time sheet and maintenance instructions are shown on Figure 5. The Physical Plant Department prints time sheets weekly, although the system allows printing daily if necessary.

The maintenance staff uses the time sheet to locate the equipment and to record time when the work is performed. The inventory number on the time sheet may be used to purchase parts or materials from the storeroom for a specific piece of equipment. The cost of repair or maintenance materials is posted directly to the equipment record at the same time the storeroom inventory is updated.

The data entry staff enters the time, inventory number, and maintenance service key, from the time sheet. A project number is also required if not pre-printed on the time sheet. The time reporting system converts the hours to cost on the basis of individual pay rates. Both the hours and the cost

Date 11/18/83 TO-BE-SCHEDULED REPORT LIFE SAFETY DIVISION Page 114
WEEK ENDING 12/09/83

LINE	ASSIGN	INVN-NO	ROOM	LOCATION	PM	FREQ	TIME	UNITS	DUE	SCHED
	THOMPSON HALL									
	FIRE ALARM SYS									
2323	-----	25530100	0014B		1	A	3.00		10/21/83 *	11/18/83
	HOSE RACKS									
2324	-----	25536000	0300S		1	A	.20		12/01/83	
2325	-----	25537100	0200S		1	A	.40	2	12/01/83	
2326	-----	25539300	0100	WEST	1	A	.20		12/08/83	
	FIRE SPRINK SYS									
2327	-----	25531200	0022A		1	A	12.00		12/08/83	
2328	-----	25532300	0223G		2	A	14.00		12/08/83	
2329	-----	25717600	0422		2	M	.50		12/08/83	
	BRYAN HALL									
	FIRE ALARM SYS									
2330	-----	25714300	011B	OUTR WALL	2	A	6.00		11/15/83	11/18/83

FIGURE 4. TO-BE-SCHEDULED REPORT

TIME SHEET

LAST NAME _____ FIRST _____ EMPLOYEE NO _____ MO DA YR 11/18/83 D6 1840

HRS	W.O. NO.	EQUIPMENT	TYPE	SET	INC			
----	820747-1	29385600	M	133		REFRC COMPRESSOR	JSN HL	0401
----	820747-1	29390400	M	133		REFRG COMPRESSOR	JSN HL	0352C
----	820747-1	29391500	M	133		REFRG COMPRESSOR AIR COMPRESSOR	JSN HL	0405
----	820747-1	29403000	M	133		REFRG COMPRESSOR COOLER RM 70	JSN HL	B0001
----	820747-1	71165300	M	133		REFRG COMPRESSOR	JSN HL	0170

INSTRUCTION SET

LAST NAME _____ FIRST _____ EMPLOYEE NO _____ MO DA YR 11/18/83 D6 1840

INSTRUCTION SET 133

REFRIGERATION COMPRESSOR.
CHECK OIL LEVEL IN COMPRESSOR THROUGH SIGHT GLASS.
BE SURE IT COVERS HALF OF GLASS WHEN RUNNING.
CHECK OIL PRESSURE IN POSITIVE PRESSURE SYSTEMS.
BE SURE IT READS BETWEEN 50 AND 70 LBS. ABOVE SUCTION PRESSURE.
CHECK FOR PROPER REFRIGERANT FLOW AND MOISTURE.
FLOW SHOULD BE CLEAR WITH NO BUBBLES.
CHECK HIGH AND LOW PRESSURE GAUGES FOR CORRECT READINGS.
REPLACE ANY GAUGES FOUND TO BE DEFECTIVE.
INSPECT ENTIRE SYSTEM FOR UNUSUAL CONDITIONS.

FIGURE 5. TIME SHEET AND INSTRUCTIONS

for maintaining a piece of equipment are posted directly to the equipment record for a specific service, and to the building maintenance project.

The service frequency hierarchy, shown on Figure 6, provides for the least frequent service to include and replace the more frequent services. When regular maintenance is posted the date the next maintenance is due is automatically computed and the dates of other services due are synchronized using the frequency interval days. Adjustment of the dates avoids, for example, having a monthly maintenance performed a week after a quarterly or annual service. Startup and shutdown services are seasonal and therefore assigned the same date each year. A next service date is never assigned automatically for on command services.

FREQUENCY HIERARCHY	INTERVAL DAYS
5 year	1825
3 year	1095
2 year	730
Annual	365
Semiannual	183
Quarterly	92
Monthly	31
Weekly	7
FREQUENCY NOT SUBJECT TO HIERARCHY	
Startup	365
Shutdown	365
On Command	NONE

FIGURE 6. MAINTENANCE FREQUENCY

An exception report provides Physical Plant management with a list of all maintenance two weeks overdue. When a maintenance is overdue, a decision can be made to change the maintenance due date. This slippage of the date is recorded on the equipment record for the specific maintenance history.

Monthly reports provide management with maintenance costs by building and supervisory area. The costs are detailed by regular maintenance, repairs, and emergency, unplanned services. These reports, together with annual reports from the project management system, provide management with the necessary information to define staff and budget requirements.

BENEFITS

In the two years since the Planned Maintenance System for equipment was implemented, the benefits sought have been realized. Physical Plant management and staff have immediate access to pertinent information concerning equipment description, including components, and maintenance

activity from the time the program was introduced. Decisions regarding replacement or repair of equipment are easier to make.

Efficient use of the maintenance staff is possible. Supervisors now plan the maintenance workload ahead of time and are reasonably certain of the requirements. Standardized maintenance tasks provide the supervisor with known task times making efficient scheduling of staff possible. The necessary parts or supplies for equipment service can be purchased ahead of time instead of using valuable labor allocations to make trips back and forth to the storeroom.

The number of emergency repairs has decreased significantly as more equipment is given proper maintenance through the Planned Maintenance System. Cost center and staff projections, normally required during the budgeting process, are available using the data elements established in the various database files Statistical information, never available by any accurate measure in the past, is now easily accessed through a computer terminal.

The most important benefit to management the Planned Maintenance System has provided, however, is the improvement in morale of the maintenance staff. Mechanics and craft people now know their workload is identified and the information resulting from their work is being used in a meaningful way.

FUTURE APPLICATIONS

The Planned Maintenance System at Washington State University was designed and developed with continuing enhancement and expansion from an established database as a precise objective. The data elements to include motor pool vehicles in the Planned Maintenance System were included in the original development project. Vehicle maintenance requirements will very soon be identified in the Planned Maintenance System. Work has already begun to include structural maintenance such as roofs, decks, exteriors and interior wall upkeep into the Planned Maintenance program. The capability of a complete facilities maintenance system now exists. Budget cuts have resulted in a significant backlog of facilities maintenance. This backlog will be entered into the database and maintenance dates assigned. Deferred maintenance will be defined by default.

The versatility and flexibility of the system have provided Physical Plant administrators with the tools they have needed and wanted for well over a decade. Administrators continue to discover new ways to use and exploit the information provided in the database.